Ms. Magalie Roman Salas 1 December 1998
Office of the Secretary
Federal Communications Commission
1919 M Street NW, Room 222
Washington, DC 20554

Dear Ms. Salas,

I have just reviewed the FCC's Notice of Inquiry in the matter of Revision of Part 15 of the Commission's Rules Regarding Ultra-Wideband Transmission Systems, FCC 98-208, ET Docket No. 98-153. The discussion under paragraph 7 mentions new beneficial uses of ground penetrating radar systems under development. It does not seem to be aware that ground penetrating radar systems have been in use since 1929, commercially available since 1972 (before that it was build it yourself), the subject of over 300 patents in the past few decades, discussed in over 4,000 papers in the scientific and engineering literature, mentioned in over 500,000 WWW sites on the internet, the subject of 7 International Conferences on Ground Penetrating Radar, and are widely used around the world for a host of applications. These applications include problems in locating lost utilities, environmental site characterization and monitoring, agriculture, archaeological and forensic investigation, unexploded ordnance and land mine detection, groundwater, pavement and infrastructure characterization, mining, ice sounding, permafrost, and many other beneficial applications. For a good overview and a set of links to activities around the world, go to http://www.g-p-r.com.

These devices emit electromagnetic radiation over broad bandwidths from 1 MHz to 3,000 MHz, at very low power levels, and very low duty cycles. They are mostly ground coupled antennas, designed to get energy into the ground, though there is some leakage into the air. I know of no complaints of interference caused by ground penetrating radar systems in my 30 years of experience, and this includes direct testing against microwave intrusion systems, television and radio reception, walkie talkies, and cellular phones. However, as ground penetrating radar systems are also ultra-wide bandwidth receivers, the reverse problem can be severe.

I have been prevented from using ground penetrating radar systems to solve problems because of radiofrequency interference that completely swamps the operation of a ground penetrating radar system. These problems typically occur in urban areas or areas with high levels of industrial, military or aerospace activity, including evaluation of pavement thickness and interstate highway condition by interference from cellular phone repeater towers in the proximity, of airport environmental contamination problems by airport tower operations and landing systems, interference from digital telemetry systems and notebook computer systems, from the communication between real-time kinematic differential GPS receiver pairs, and so forth. I've learned to work around these problems using digital filtering, working at odd hours, or asking that something be turned off. I've never been asked to turn the radar off because it was causing a problem.

Ground penetrating radar has the highest resolution of any tool for noninvasive subsurface investigation. It is one of the very

few tools capable of seeing nonmetallic things in the subsurface like organic chemical contamination, plastic land mines (humanitarian demining), plastic natural gas pipes, mapping fine scale soil structure necessary to foster plant growth in agriculture, and other applications as noted above. It is one of the vital tools in the toolbox of geophysics, with many significant beneficial uses.

The Notice of Inquiry asks some specific questions, but also misses a few key questions that should be asked. I'll attempt to answer the NOI questions, and suggest a few of my own.

In paragraph 9:

What kinds of UWB devices can we expect to be developed?

Many different kinds for many different purposes, but I would hope competing solutions would also be investigated, so there aren't so many devices that the rising average background noise level wipes out the use of all such devices.

What are the frequency ranges, bandwidths, power levels, etc. expected to be used by UWB devices?

Anything from 1 kHz to 10 GHz, with GHz bandwidths, peak powers of watts but very low duty cycles (less than 0.001 fractional
on time) and average powers of less than milliwatts.

What are the expected or desired operating distances?

Current ground penetrating radar devices operate over distances of a fraction of a meter (evaluating pavement thickness) to 5,400 meters (depth sounding of ice in polar regions).

You should also ask, how many units can be expected to be manufactured of any given kind of UWB device?

There are less than 2,000 ground penetrating radars (also called georadar, ground probing radar, subsurface radar) in the world. It is not likely that this number will increase by orders of magnitude, though the demand from solutions of large problems could easily increase this number by a factor of 2 to 10, mostly limited at the present time by the numbers of people available who know how to use one properly. The 7 International Conferences on Ground Penetrating Radar have each attracted registered attendances on the order of 200 people, with mailing lists to interested parties numbering in the 2,000 range. (I hosted the 3rd International Conference in Denver in 1990 and was the invited keynote speaker in 1988, 1992 and 1996.)

You should also ask, how will the UWB systems be used?

Ground penetrating radar systems are designed with underground exploration, characterization or investigation of some sort in mind. This means they need to efficiently get the EM energy into the ground. What are the system parameters describing this coupling to the ground, what does the operator need to do to maximize this coupling, how can the operator tell than he's producing too much leakage into the air (which will produce artifacts in the radar data record)? How can the operator be prevented from misusing the instrument?

In paragraph 10:

Are there certain types of UWB devices or applications that should be regulated on a licensed basis...?

Probably on the basis of peak power, duty cycle and average power radiated into the air (as most of the power should be radiated into the ground if setup and working properly) and potential for operator misuse.

How should UWB technology be defined?

In terms of bandwidth, spectral coverage, and power into the air. Airborne and satellite ground penetrating radar systems radiate into the air, with a small fraction getting into the ground. Ground coupled radars (that sit on the surface of the ground) are designed to put most of their power into the ground. Borehole radar systems put almost all their power into the ground and very little or none into the air. So the air launch radars should require regulation and licensing, but the ground coupled and borehole systems should not require either (though there may be an operator training issue or necessity to build into the design hardware features that prevent misuse).

Paragraph 11:

Should the rules prohibit operation in the restricted or TV broadcast bands?

No. This would defeat the purpose and physics of most of the systems, make ground penetrating radar prohibitively expensive, and destroy a very beneficial use of geophysical tools.

Paragraph 12:

Are the existing general emission limits sufficient to protect...

As I know of no known instance of interference caused by ground penetrating radar, the current limits seem adequate.

Should different limits be applied to UWB systems?

Yes. Systems launching radiowaves into the air should be regulated differently from those launching directly into the ground (from surface contact or in a borehole).

Should we specify a different standard for UWB devices based on spectral power density?

Yes, and also on usage in terms of getting energy into the ground versus the air.

Should these standards be designed to ensure that emissions appear to be broadband noise?

This is possible but not advisable. For some problems, cross-correlation of the noise is enough to solve a wide variety of problems. But issues of signal-to-noise and instrument dynamic range need to be thought through. This is especialy true if there are a lot of
devices raising the average noise levels.

What is the potential for harmful interference ...large proliferation...

Negligible, as already mentioned, the quantity of ground

penetrating radar systems is limited by a variety of factors to a few thousand on a world wide basis. Each system typically operates over a very limited fraction of the work day. They're never all on at once. I've done tests with two comparable ground penetrating radar systems simultaneously on and measuring within a few meters of each other with no noticable interference between the systems (because of the low duty cycles, the odds are very small that they'll be making measurements at the same time). The most noticable effect was the disturbance from the laptop computer or the cellular phone to the radar receiving antenna.

Should a limit on the total peak level apply to UWB devices?

For ground penetrating radar, this should be expressed in terms of the total peak level getting into the air and not include that getting into the ground.

Can filtering improve potential interference without reducing performance?

No. One of the things we try to characterize is the "filter" provided by the Earth. Adding more filters complicates this. Some radar systems have a computer built into the radar hardware, but I prefer it to be separate. When the computer is built in, it provides RFI inside the radar instrument that must be filtered out. Often, this filtering to remove the computer noise also removes filter characteristics of the earth that would be very valuable in characterizing water content, plastic land mines, and so forth.

Are existing limits on the amount of power permitted to be conducted back into the AC power lines appropriate for UWB devices?

Yes, again as I know of no case of interference, but also because most ground penetrating radar systems are battery operated.

What operational restrictions, if any should be required to protect existing users?

Mostly how to be efficient in getting energy into the ground, minimizing energy in the air, and computer software or hardware to prevent misuse of the equipment.

Paragraph 13:

Are there any other changes to the measurement procedures that should be applied to UWB devices?

For ground penetrating radar, the tests should be done in the normal mode of operation with the antenna coupled to and putting energy into the ground. As the antennas are designed for a particular ground coupling (e.g. the electrical and magnetic properties of what the manufacturers consider a typical soil), they should be tested in that optimum case as well as coupled to soils of different types and water contents to see the effects of worst case mismatch with varying soil type and condition (and season). This will determine the amount getting into the air under optimal and worst case scenarios. These should also take into account typical decoupling scenarios in which the antennas are carried or towed along the surface of the ground, with decoupling events related to being bounced off the surface, lifted over obstacles, and so forth.

Paragraph 14:

Should the prohibition against Class B, damped emissions apply to UWB...?

No. Not only for the low power reasons but because the definition is not clear.

...other matters or issues that may be pertinent...

If there occurs a widespread dissemination of UWB devices for garage door openers, communications devices, and so forth, collectively raising the average background RF noise level, this will create problems for the use of ground penetrating radar. This is the reverse of the RFI you intended this discussion to address.

But ground penetrating radar has many beneficial uses as already noted. If these other UWB devices become widespread, it would be nice to have a window of time (like 12:00am to 5:00am) when all such other devices would be required to be turned off so we could still do ground penetrating radar surveys. Otherwise, a very powerful tool for subsurface investigation will be denied to us, and there is no viable substitute.

In this last regard, there are a large number US state and federal government agencies who are frequent users of ground penetrating radar, and I estimate the US Federal Government spends about $60,000,000/year on ground penetrating radar applications or research: US Army, USNavy, US Geological Survey, Federal Highway Administration, NIST, NASA, US DOE, US EPA, FBI, US Dept of Agriculture, and many more who might be asked to comment on this NOI. There have been two Ground Penetrating Radar Government Users Conferences. I used to work for the USGS doing ground penetrating radar geophysics (for nearly 20 years), and I could suggest names of people to involve if you need more comment.

Sincerely,

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